

## CLAIMS:

1. A ferromagnetic thin-film based magnetic field sensor, said sensor comprising:

a substrate; and

a plurality of sensing structures supported on said substrate each comprising:

a nonmagnetic intermediate layer, said nonmagnetic intermediate layer having two major surfaces on opposite sides thereof;

a magnetization reference layer on one of said nonmagnetic intermediate layer major surfaces having a relatively fixed magnetization direction; and

a sensing film of an anisotropic ferromagnetic material on that remaining one of said nonmagnetic intermediate layer major surfaces having a length in a selected length direction and a width smaller in extent substantially perpendicular thereto but substantially parallel to said relatively fixed magnetization direction; and

a first sensitive direction sensing structure and a second sensitive direction sensing structure in said plurality of sensing structures each having said relatively fixed magnetization direction of said magnetization reference layer therein oriented in substantially parallel to said substrate but substantially perpendicular to one another.

2. The apparatus of claim 1 wherein at least one of said first and second sensitive direction sensing structures further comprises a spacer layer on said sensing film and across said sensing film from one of said nonmagnetic

intermediate layer major surfaces, said spacer layer having a major surface on a side thereof opposite said sensing film; and an augmenting film of an anisotropic ferromagnetic material on said spacer layer major surface with said spacer layer being sufficiently thick so as to significantly reduce or eliminate topological coupling between said sensing and augmenting films and to significantly randomize spin states of emerging electrons traversing therethrough.

3. The apparatus of claim 1 wherein said magnetization reference layer in at least one of said first and second sensitive direction sensing structures comprises an anisotropic ferromagnetic material.

4. The apparatus of claim 1 wherein said magnetization reference layer in at least one of said first and second sensitive direction sensing structures is a first magnetization reference layer, and further comprises a second magnetization reference layer provided on that same one of said nonmagnetic intermediate layer major surfaces as said first magnetization reference layer, and also having a relatively fixed magnetization direction .

5. The apparatus of claim 1 wherein said sensing film in at least one of said first and second sensitive direction sensing structures has a shaped end portion extending over a portion of said length in which said width gradually reduces to zero at that end thereof.

6. The apparatus of claim 1 wherein a said nonmagnetic intermediate layer in at least one of said first and second sensitive direction sensing structures is an electrically insulative layer.

7. The apparatus of claim 1 wherein a said substrate comprises a monolithic integrated circuit.
8. The apparatus of claim 1 further comprising a first sensitive direction supplemental sensing structure in said plurality of sensing structures having said relatively fixed magnetization direction of said magnetization reference layer therein oriented in substantially parallel to said substrate and substantially parallel to said that of said first sensitive direction sensing structure.
9. The apparatus of claim 1 further comprising a first magnetically permeable mass having said first sensitive direction sensing structure positioned adjacent to one side thereof and having said second sensitive direction sensing structure positioned adjacent to another side thereof.
10. The apparatus of claim 2 wherein said sensing film and said augmenting film together have a length along a selected direction and a width substantially perpendicular thereto that is smaller in extent than said length, and together have a shaped end portion extending over a portion of said length in which said width gradually reduces to zero at that end thereof..
11. The apparatus of claim 3 wherein said magnetization reference layer is a composite layer and, in addition to a ferromagnetic material layer therein, further comprises an antiferromagnetic material layer therein.
12. The apparatus of claim 8 wherein said first sensitive direction sensing structure and said first sensitive direction supplemental sensing structure are each electrically connected in a common bridge circuit.

13. The apparatus of claim 9 further comprising a shielded sensing structure in said plurality of sensing structures positioned between said first magnetically permeable mass and said substrate.

14. The apparatus of claim 13 wherein said first sensitive direction sensing structure, said first sensitive direction supplemental sensing structure and said shielded sensing structure are each electrically connected in a common bridge circuit.

15. A method for fabricating a ferromagnetic thin-film based magnetic field sensor comprising a substrate supporting first and second sensitive direction sensing structures, said method comprising:

forming said first and second sensitive direction sensing structures supported on said substrate each comprising a nonmagnetic intermediate layer having two major surfaces on opposite sides thereof with a magnetization reference layer on one of said nonmagnetic intermediate layer major surfaces which can be provided with a relatively fixed magnetization direction and a sensing film of an anisotropic ferromagnetic material on that remaining one of said nonmagnetic intermediate layer major surfaces having a length in a selected length direction and a width substantially perpendicular thereto such that said length direction of said first sensitive direction sensing structure is perpendicular to said length direction of said second sensitive direction sensing structure; and

annealing said sensor at an elevated temperature while applying an external magnetic field substantially parallel to said substrate at an angle half way between said sensing film length directions of said first and second sensitive direction sensing structures.